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Research of Processes of a Deep Aerobic Mineralization of Activated Sludge

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Abstract

The article describes the process of deep aerobic mineralization of activated sludge in municipal wastewater treatment plants using a complex of aerobic heterotrophic and autotrophic microorganisms, including denitrifiers.

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Keywords: deep aerobic mineralization, activated sludge, sludge treatment.

1. Introduction

In the countries of the European Union the technical policy in the field of utilization of sewage settlings of urban wastewater becomes tougher every year. In the existing sewage treatment technologies, after primary sedimentation tank, sewage settlings are surely formed. Also the excess activated sludge produced after constructions of biological treatment. The volume of sediments which are formed in the course of sewage treatment depending on the pollution concentration in waste liquid makes more than 0.5% of sewage volume [1, 2]. From the economic point of view it is more expedient to use sediments in agriculture or to store them on separate sludge beds. However, existence of a large number of pathogenic microorganisms, surface-active substances and ions of heavy metals in sediments restrain their use in agriculture [3, 4]. In certain cases it is recommended to use various methods of thermal processing (thermal drying, thermal aerobic and anaerobic stabilization, etc.) for the liquid and dewatered

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sludge [5, 6]. Because of high power expenses these methods didn't find widespread introduction in practice of sediments utilization [7, 8].

Expenses from urban wastewater treatment plants in the mode of the extended aeration can make from 335 to 760 Euro/t of dry solid, that is valid to the plants with power 10-400 thousand eguiv. - inhabitants. It makes about 7.6-16.7 Euro/year for one eguiv. inhabitant, or 0.1-0.3 Euro/m^3 of treated water [1, 2].

For ecological and economic reasons the most perspective method of excess sludge utilization can be considered the deep aerobic processing of sediment by a complex of the heterotrophic and autotrophic microorganisms in constructions with the flooded airlift system of aeration [9]. This method differs from a method of the extended aeration by the increased extent of destruction of ashless part of activated sludge organic substance.

2. Problem statement

Today a product of biological wastewater treatment – excess sludge is considered as a main byproduct of sewage treatment.

By estimates of the independent expert organizations today municipal treatment facilities all over the world make annually more than 200 million tons of sediments [1, 18].

Today natural ecosystems aren't able to cope with such quantity of the incoming sediment which can cause an ecological disaster.

Modern researchers proved prospects of a method of deep aerobic sludge treatment in the field of processing of sediments [10, 11].

The aim of these researches was further studying of process of a deep aerobic mineralization in constructions with the flooded airlift system of aeration, including processes of nitri – denitrification.

The main task of research is definition of basic technological parameters of deep aerobic mineralization of activated sludge.

3. Specimens and test procedure

Researches were conducted with excess activated sludge produced at the station of biological treatment – household sewage in Suderburg included in the district of Uelzen in Lower Saxony (Germany).

City treatment facilities of Suderburg have non-standard, for Ukraine, scheme of sewage treatment. The population of the city of Suderburg makes 4686 people.

The peculiarity of the Suderburg city sewage is that it is located in the agriculturally developed region, so wastewater with high salt content often fall to the treatment plants.

Wastewater by gravity sewers enter the receiving chamber, from where it goes to the mechanical treatment facilities.

Then waste liquid goes to biological treatment plants in the form of the circular-oxidative channels (CSC) working by the principle of simultaneous removal of nitrogen and organic pollution [12, 13]. This method differs in that process is carried out in one construction without separate allocation aerobic and the anoxic zones, and also recirculation streams of sludge mix. CSC construction works on the principle of variable aeration for the effective combination of nitri - denitrification in the volume of one construction.

The final purification step is the separation of the activated sludge from the secondary radially settler after which it goes to an anaerobic stabilization, to biogas receiving, followed by further compacting and disposing.

The excess activated sludge is characterized by high content of phosphorus accumulated in bacterial cells and high sludge index up to 140 ml/g.

Sludge concentration of dry matter of 4.0-6.5 g/dm^3, pH 6.5-7.5, the ash content in the range of 20.5-25.0%, COD interstitial water of 25-50 mg/dm^3, salinity (referred to the NaCl) 0.33-1.36 g/dm^3.

Contents of forms of mineral nitrogen in the sludge water N-NH_4^+=0.1-2 mg/dm^3, N-NO_2^-= 0.1-0.4 mg/dm^3, N-NO_3^-= 3-30 mg/dm^3, P-PO_4^{2-}= 0.3-1.8 mg/dm^3. The temperature of the supplied sludge mixture is in the range 15-21 °C.

The process of biological oxidation (mineralization) of the activated sludge biomass lies in use of ashless sludge as a nutrient medium.

During the deep aerobic mineralization heterotrophic aerobic bacteria and denitrifiers gain primary development [14].

For the deep mineralization of activated sludge processes studying, the experimental laboratory installation working in the continuous mode within two months was created.

The laboratory installation consists of a body mineralizer (1) of 22 dm^3 (Fig. 1), which established the flooded airlift aeration system (2), which provides an upwardly – descending circulating currents. Airlift system forms a closed circulation flow: upward inside the body and descending air lift for a water lifting pipe. The relative deepening flooded airlift L/H (see. Fig. 1) was taken equal to 0.3 [15].

The system of pressure flotation is applied to separation of sludge mixture from sludge water (7). The sludge mixture is taken away on the pipeline (4), through a pressure saturator of 3 dm^3 (6) where it is sated with oxygen under pressure of 4.0-5.0 bars. Then the separated biomass comes back in an aerobic mineralizer.

In a zone of intensive aeration concentration of the dissolved oxygen was maintained at the level of 4-4.5 mg/dm3, and in the bottom part 0.5-1.0 mg/dm^3. Over the flooded airlift the zone of intensive aeration was formed and supported. Control of concentration of the dissolved oxygen in water was exercised by means of sensors of the dissolved oxygen (10, 11).

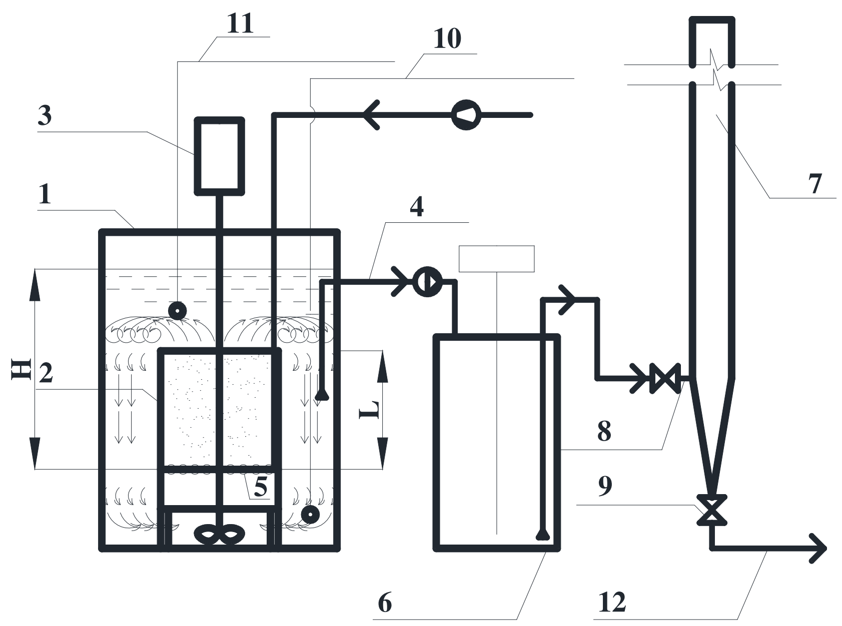

Fig. 1. Scheme of experimental installation of a deep mineralization of activated sludge: 1 – mineralizer; 2 – flooded airlift aeration system; 3 – mixer; 4 – sludge supply pipeline; 5 – air supply; 6 – saturator pressure flotation; 7 – flotation column; 8 – submission of saturated sludge mixture; 9 – adjusting valve; 10 – dissolved oxygen sensor; 11 – paired sensor dissolved oxygen, pH and salinity; 12 – pipeline removal activated sludge and sludge water.

For a sludge bedding exception in bottom part hashing by means of a mixer was carried out (3).

In scientific articles [10, 11, 17] the foundation is given and the basic possibility of implementation of technology of the deep (prolonged) aerobic mineralization of a deposit, by laboratory researches, is shown.

Performance of processes of a mineralization is reached by means of deduction in a construction of certain forms of microorganisms and bacteria, as a rule, having quite high "age" [10, 11, 16, 19, 20], capable to continue an aerobic mineralization with the lowered rate of decay of organic part of activated sludge. According to these researches the duration of an aerobic mineralization of 11 days was accepted. Daily mineralizer was loaded with 2 dm^3 source activated sludge sampled from the production of the secondary clarifier. Previously having separated 2 dm^3 of sludge water on floatation installation, and the separated deposit came back to a mineralizer.

Thus indicators of the loaded sediment and activated sludge in an aerobic mineralizer were fixed.

Controlled parameters: concentration of the dissolved oxygen of various zones, salinity, mixing intensity in the mineralizer, COD, forms of mineral nitrogen to N-NH_4^+, N-NO_2^-, N-NO_3^-, and organic Norg, the content of phosphorus, a sludge index, working temperature, pH, structural changes of activated sludge cell over time, the working pressure of floatation installation, concentration of activated sludge of the given and taken away mixture, and also its ash-content.

4. The research results

According to the obtained data a number of graphic dependences at which processing the main processes of a deep mineralization (Fig. 2, 3) are constructed.

During all experiment the balance of decay of organic sludge, as well as transformation of nitrogen compounds was fixed. As a result a specific rate of decay of the organic sediment in the mineralizer, depending on a concentration of activated sludge on ash-free substance was received. Concentration of activated sludge on ashless substance MLVSS changed from 3.8-10.6 g/dm^3.

It has been established that the specific rate of decay increasing with the concentration of activated sludge in the aerobic mineralizer decreases from 3.5 to 1.4 mg/g hour.

In an initial stage of operation daily decay of organic part of activated sludge made 6700 mg/day, and by the end of experiment made 7500 mg/day.

Specific rate of decay was defined according to the equation of balance of an aerobic mineralizer (Eq. 1).

$$\rho = \frac{\Delta M}{\left(C_{VSS} \times W_{\min} \times t\right)}, \tag{1}$$

where ρ – specific rate of decay of the organic part of the activated sludge, mg/g, hour;
ΔM – destructible sediment mass, mg;
C_{VSS} – concentration of activated sludge on the ash-free substance, g/l;
W_{min} – working volume of mineralizer, dm^3;
t – processing time, hour.

It is experimentally established that at disintegration of organic part of sediments processes of a nitri-denitrification in parallel proceed. The induced balance in all forms of nitrogen allowed to establish the average specific speed of removal of the total nitrogen which made 0.15 mg/g hour. Thus, at a deep mineralization of aerobic heterotrophic denitrifying microorganisms and removal of nitrogen consumed 1 mg 8-11 mg of the organic part fo the activated sludge. Active reaction of the environment practically remained invariable during all experiment and made 6.0-7.3. The effect of destruction of ashless part of a sludge made 65%.

A temporary increase in the concentration of dissolved oxygen in the bottom zone of up to 2.5 mg/dm^3 promoted the inhibition of the denitrification process, and as a result, increase in the concentration of nitrates. The effect is the destruction of organic sludge was reduced to 25%.

It is noted that the ash content in the mineralization of sludge at the end of the experiment increased from 20% to 29%, with an average ash content of initial sludge 22% (Fig. 3).

Average value of an ash-content of sludge in the clarified water after flotation makes 35%.

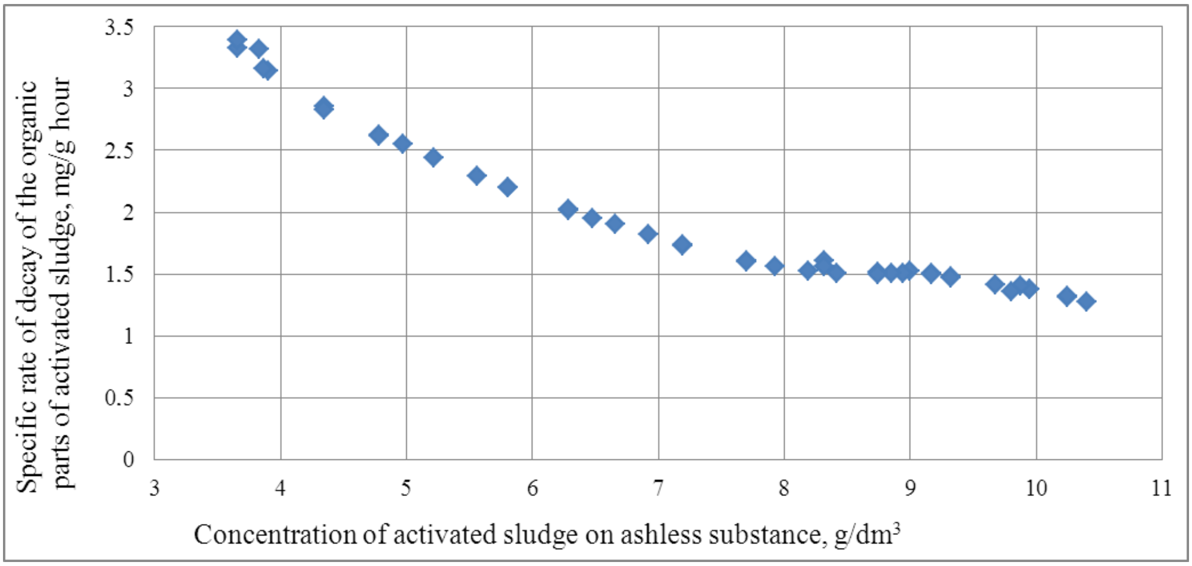

Fig. 2. Dependence of the specific rate of decay of the organic part of the activated sludge from the sludge concentration.

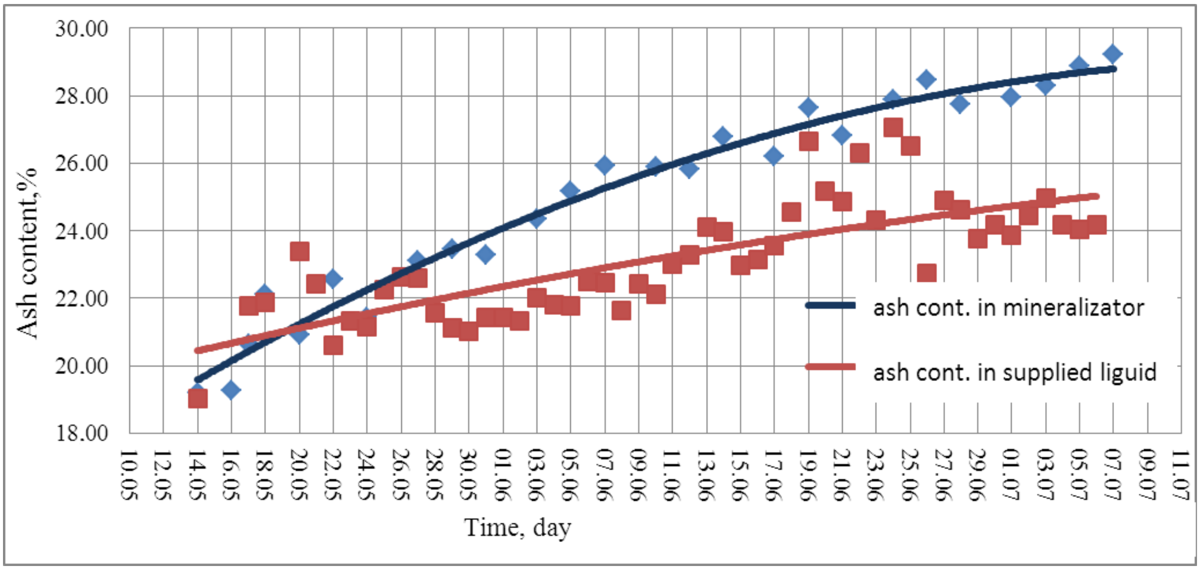

Fig. 3. Change of an ash-content of activated sludge in a mineralizer and the loaded activated sludge

5. Summary

1. Specific rates of decay of organic part of the activated sludge processed by a complex the heterotrophic aerobic microorganisms including denitrifiers are received. Depending on various concentration of ashless part of activated sludge, it makes 3.5-1.4 mg/g hour.

2. It is established that parallel to processes of a deep aerobic mineralization processes of a nitri-denitrification proceed. The average specific removal rate of total nitrogen was 0.15 mg/g hour. 8-11 mg of organic part of activated sludge are spent for removal of 1 mg of nitrogen.

3. The effect of destruction of ashless part of a deposit in a construction of a deep aerobic mineralization of sludge makes 65%.

4. Average value of an ash-content of sludge in the clarified water makes 35% that considerably exceeds a sludge ash-content in an aerobic mineralizer. Due to flotation processing sludge water finely dispersed sludge with high ash content is removed.

References

[1] Gerasimov, G.N. Obrabotka osadkov stochnykh vod [Treatment of sewage water sediments] (2008) Vodosnabzhenie i sanitarnaya tekhnika, 12, pp. 67-71.

[2] Gerasimov, G.N. Reshenie problemy obrabotki vodoprovodnykh i kanalizatsionnykh osadkov [Solving the problem of water and sewage sludge treatment] (2003) Vodosnabzhenie i sanitarnaya tekhnika, 1, p. 43-47.

[3] Lukashevich, O.D., Barskaya, I.V. Ekologicheskie problemy obrabotki i utilizatsii osadkov stochnykh vod [Ecological problems of sewage sludge treatment and utilization] (2007) Ekologiya promyshlennogo proizvodstva, 3, pp. 68-75.

[4] Ol'khov, A.A., Berlin, A.A., Iordanskii, A.L., Vatin, N.I., Zaikov, G.E. Morphology and parameters polyethylenepolyhydroxybutyrate biocomposite (2014) Chemistry: state and development prospects, Grozny, pp. 391-403.

[5] Betriebsprobleme auf Kläranlagen durch Blähschlamm, Schwimmschlamm, Schaum; Prof. Dr.-Ing. Dr. phil. Sabine Kunst, Dr.-Ing. Helmer, Dr.-Ing. Silke Knoop (2000) Springer-Verlag Berlin Heidelbberg, 175 p.

[6] Wastewater Engineering: Treatment and Reuse, George Tchobanoglous, Franklin L. Burton, H. David Stensel, McGraw Hill Higher Education; Medcalf & Eddy ink.; 4th edition (2002) 1819 p.

[7] Delalio, A., Goncharuk, V.V., Kornilovich, B.Yu. et al. Utilizatsiya osadkov gorodskikh stochnykh vod [Recycling of urban wastewater sediments] (2003) Khimiya i tekhnologiya vody, 25 (5), pp. 458-464.

[8] Danilovich, D.A., Kozlov, M.N., Adzhienko, V.E. et al. Perspektivnye tekhnologii v oblasti obrabotki osadkov [Promising technologies in the field of sediments treatment] (1996) Vodosnabzhenie i sanitarnaya tekhnika, 1, pp. 12-14.

[9] Nezdoyminov, V.I., Bereza, G.M., Razumov, A.Yu. Deklaratsiyniy patent na korisnu model'. №20040402868 vid 17.01.2005. Pristriy dlya ochishchennya stichnikh vod aktivnim mulom [Construction for wastewater treatment by means of activated sludge] (2005).

[10] Nezdoyminov, V.I., Chernyshev, V.N. Novaya ekologicheski bezopasnaya tekhnologiya utilizatsii osadkov [The new Environmentally safe technology of sediments utilization] (2010) MOTROL, 13, p. 17-23.

[11] Chernyshev, V.N., Kizhaev, V.F. Biotekhnologiya glubokoy mineralizatsii osadkov gorodskikh stochnykh vod, soderzhashchikh iony tyazhelykh metallov [Biotechnology of deep mineralization of urban waste water sediments containing heavy metal ions] (2010) Kharkiv, p. 133.

[12] Vasil'yev, V.B., Vavilin, V.A. Odnovremennoe udalenie soedineniy azota i organicheskogo ugleroda iz stochnyyi vod mnogovidovym soobshchestvom mikroorganizmov [The simultaneous removal of nitrogen and organic carbon from waste water by means of multispecies microbial community] (1990) Vodnye resursy, 1, pp. 119-127.

[13] Lyubchenko, O.A., Mogilevich, N.F., Gvozdyak, P.I. Mikrobnaya nitrifikatsiya i ochistka vody [Microbial nitrification and water treatment] (1996) Khimiya i tekhnologiya vody, 18 (1), pp. 98-112.

[14] Nezdoyminov, V.I., Chernyshev, V.N. Tekhnologiya biologicheskogo udaleniya soedineniy azota pri defitsite organicheskogo substrata [The technology of biological removal of nitrogen in deficiency of organic substrate] (2005) DonDABA, pp. 23-26.

[15] Nezdoyminov, V.I., Golodenko, N.N. Komp'yuternoe modelirovanie dvizheniya gazozhidkostnoy smesi v zatoplennom erlifte [Computer modeling of motion-liquid mixture in the flooded airlift] (2011) Visnik Odes'koi DABA, 42, pp. 161-168.

[16] Chernishev, V.N., Ziatina, V.I. Issledovaniya raboty ilootdelitelya v tekhnologii glubokoy mineralizatsii osadka [Researches of work of an sludge removing in technology of a deep mineralization of sediments] (2013) DonNASEA, 2013-3 (101), pp. 85-88.

[17] Nezdoyminov, V.I., Chernyshev, V.N. Eksperimental'nye issledovaniya glubokoy mineralizatsii osadkov v proizvodstvennykh usloviyakh [Experimental research of deep mineralization of sediments in the industrial conditions] (2011) Naukoviy Visnik budivnitstva, Kharkiv, 63, pp. 498-501.

[18] Chechevichkin, V., Vatin, N. Megacities land drainage and land runoff features and treatment (2014) Applied Mechanics and Materials, 641-642, pp. 409-415.

[19] Bezborodov, S., Zemlynaya, N. Determination of Wastewater Purification Index under Joint Action of Several Pollution Sources in Marine Water Areas (2015) Applied Mechanics and Materials, 725-726, pp. 1350-1356.

[20] Gogina, E., Ruzhitskaya, O. One-Sludge Denitri-Nitrification System Application in Reconstruction of Biological Treatment Stations in Russian Federation (2015) Applied Mechanics and Materials, 725-726, pp. 1325-1331.